Pressure alterations along the arterial tree during atrial fibrillation

PRESSURE ALTERATIONS ALONG THE ARTERIAL TREE DURING ATRIAL FIBRILLATION

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Introduction

Atrial fibrillation (AF) is the most common form of arrhythmia. It can lead to both heart failure and stroke and is responsible for an increase in cardiovascular morbidity and mortality [1]. In spite of its importance, the direct effects of AF on arterial pressure patterns are not completely known. In fact, literature data report conflicting pressure trends, oscillometric instruments for invasive measures do not work properly in AF (because of the heart rate fluctuations), and the net role of AF is not easy detectable since it usually combines with other pathologies. In this context, we give new insights into the pressure response of the large-to-medium arteries system to AF, by adopting a physically-based multi-scale modelling approach of the left heart and arterial systemic circulation.

Methods

Our work exploits the multi-scale mathematical model by Guala et al. [2,3], solved numerically through a Discontinuous-Galerkin scheme. Through it, we obtain the detailed pressure (and flow rate) signals along the arterial tree during an episode of AF lasting around ½ hour (2000 heartbeats). Geometries and properties of the heart and arterial vessels refer to a healthy young adult, and no other pathologies often correlated to AF are considered. The sequence of fibrillated heartbeat periods, RR, is extracted from an uncorrelated Exponentially Modified Gaussian distribution, as expected in AF [4,5]. μ_{RR}=0.8s is the mean value while σ_{RR}=0.19s is the standard deviation of the RR intervals.

Results

Figure 1 shows some examples of the pressure time series during both AF and normal sinus rhythm (NSR) - at the same mean heart rate (75 bpm) - at different sections along aorta. Interesting hints can be drawn by the probability density function PDF of the systolic and diastolic pressure values in AF, at various distances from the heart, for all the 2000 heartbeats. An example for the brachial artery is provided in *Figure 2a*. We find that, at each site, systolic and diastolic pressures vary between 7-8% and 13-16%, respectively, while their mean values are slightly higher than those evaluated in NSR. The coefficient of variation c_v, ratio between the standard deviation, σ, and the mean value, μ, of the PDF, reduces for the systolic pressure while it increases for the diastolic pressure, with the distance from the heart. Moreover, c_v values for the diastolic pressure almost double those for the systolic pressure everywhere (*Figure 2b*). Regarding pulse pressure, it fluctuates less than systolic and diastolic ones in AF (*Figure 2a*), but arterial system tends to amplify these oscillations, going towards the distal regions, similarly to what happens for the diastolic pressure (*Figure 2b*).

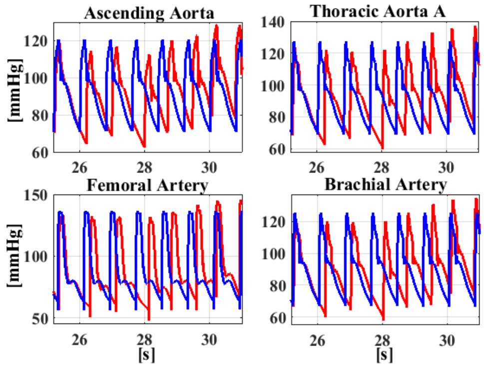

Figure 1: Examples of pressure time series during AF (red) and NSR (blue) - at the same mean heart rate (75bpm) -, at the entrance of the reported vessels.

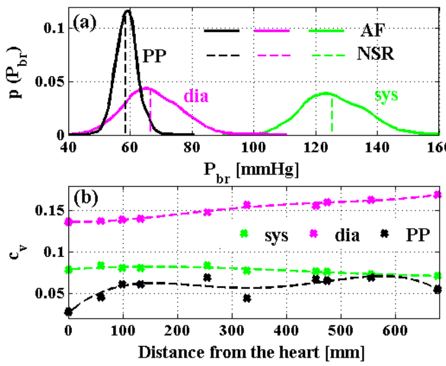

Figure 2 : (a) PDFs at the brachial artery and (b) trends of c_v values with the distance from the heart, for the systolic, diastolic and pulse pressures.

Discussion

The present approach proves to be a powerful in silico tool in revealing pressure alterations during AF. In fact, it provides, beat by beat, all the global pressure signals at any arterial section. Thus, it can be used to examine the role of AF on relevant physical phenomena, such as the pressure wave propagation and reflection.

References

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